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# ESTIMATING THE SUSCEPTIBILITY OF WILDLAND VEGETATION TO TRAILSIDE ALTERATION

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## SUMMARY

(1) Trailside vegetation was compared with undisturbed vegetation in a variety of vegetation types in a wilderness area in the northern Rocky Mountains, Oregon, U.S.A.

(2) Cover was reduced and floristic composition changed along trails.

(3) Measures of changes in cover and floristic composition were used to evaluate the relative susceptibility of different vegetation types to trailside alteration.

(4) Densely forested vegetation was more altered by trails than the vegetation of meadows or open forests.

## INTRODUCTION

Unrestricted recreational use of natural areas tends to damage the plant communities which have been selected for preservation and protection. Recent increases in the use of these areas has accelerated this destruction and created an urgent need for ecological research designed to minimize this conflict between use and preservation.

Vegetation along trails is particularly vulnerable to damage and trails must frequently be rerouted in an attempt to minimize destruction of the vegetation. The decision to relocate trails is usually based upon intuitive assessments rather than reasoned analyses of clearly understood ecological processes. Managers of natural areas need more information on the relative susceptibility of different vegetation types to changes resulting from trail construction and use. With this knowledge they could rationally design trail systems which avoided those vegetation types most susceptible to damage.

This paper proposes a method for quantitatively assessing the relative susceptibility of vegetation types to trailside change and applies this method to the major vegetation types of Eagle Cap Wilderness, a rugged, mountainous region in northeastern Oregon.

### *Characteristics of trailside vegetation*

Trail construction and use affects the trailside vegetation in the varied ways illustrated in Fig. 1. Both the direct and indirect effects of trampling have been investigated extensively since the pioneering work of Bates (1935). Researchers have used a combination of analytical and experimental techniques to study the responses of vegetation to trampling (Liddle 1975). Other mechanisms of change, such as brush removal, earth movement, and changes in drainage are also significant, but they have been only casually observed (Dale & Weaver 1974; Cole 1977). Removal of vegetation can increase direct precipitation and light intensity along trails. Alterations in slope angles

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and drainage conditions, the addition of nutrients in animal excreta, and new vectors of plant dispersal also affect plant communities along trails.

One consistent feature of trailside vegetation is a pronounced variation in the amount of plant cover. The heavily trampled centre of the trail is usually bare, but cover increases with distance from the trail to a maximum, reached approximately 1 m from the trail. This amount of cover is usually maintained in the undisturbed vegetation (Bayfield 1971; Dale & Weaver 1974).

Complications of this simple model do occur, however. Plant cover may increase in response to very low levels of trampling, so that the cover found 1 m from the trail centre may exceed that found in untrampled areas (Bayfield 1971). Changes resulting from site

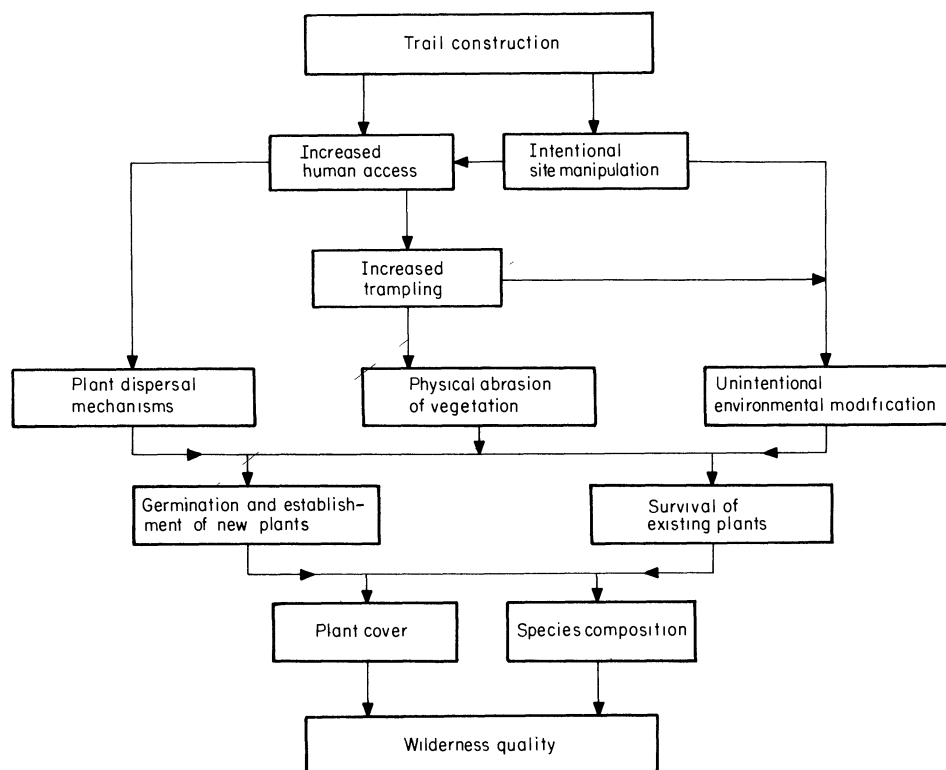


FIG. 1. A model, based in part on Liddle (1975), which illustrates significant causally-linked effects of trail construction.

manipulation, such as increased light and precipitation, may also result in a greater amount of plant cover at the periphery of the trampled zone.

Trailside plant communities usually contain both locally occurring species and invaders from other sources, which are favoured by the environmental conditions adjacent to trails. The most conspicuous invaders at low elevations (< 1800 m) in the mountainous western U.S.A. are Eurasian weeds (e.g. *Poa pratensis* L. and *Trifolium repens* L.). At higher elevations the invading species are typically from neighbouring alpine snowbank or meadow communities. The most common local survivors along trails are species with rhizomes or small, ground-level leaves, and tussock graminoids which have protected vegetative and floral perennating tissues (Dale & Weaver 1974; Cole 1977).

Most researchers have studied the resistance of individual species or growth-forms to trampling; there have been few attempts to assess the vulnerability of an entire plant community to all of the ecological changes which result from trail proximity. Liddle (1975) proposed a measure of vulnerability based on the amount of trampling an unworn plant community 'can withstand before the vegetation is reduced to 50% cover or biomass'. This experimental technique provides a measure of vulnerability to abrasion, but it does not include longer-term changes resulting from either the regenerative ability of the vegetation or responses to mechanisms of change other than direct trampling.

Analytic studies of existing trailside vegetation reveal longer-term responses because these plant communities have had time to adjust to trail proximity. Changes in vegetation can be measured directly by comparing vegetation adjacent to the trail with neighbouring undisturbed vegetation of the same basic type. The characteristics of the vegetation which appear to be most sensitive to trailside alteration are species composition and the amount of plant cover. Consequently the relative susceptibility of different vegetation types can be estimated from comparisons of the amount of change in plant cover and species composition which occur along trails in each vegetation type.

## METHODS

In order to test the feasibility and utility of such an approach, I sampled the understorey vegetation along trails in eight vegetation types frequently found in Eagle Cap Wilderness and other parts of the northern Rocky Mountains: (1) *Pseudotsuga menziesii*/*Physocarpus malvaceus* forests of lower elevation (1500–1800 m) bouldery slopes, which are characterized by scattered trees and a dense tangle of tall shrubs; (2) *Pseudotsuga menziesii*/*Calamagrostis rubescens* savannas of mid-elevation (1600–2000 m) straight slopes, with widely spaced trees and a lush growth of grasses; (3) *Picea engelmannii*/*Thalictrum occidentale* forests of mid-elevation (1600–2000 m) valley bottoms, with a dense tree stratum and an understorey of mesophytic forbs; (4) *Pinus contorta*/*Vaccinium scoparium* forests of mid-elevation (1750–2100 m) rocky flats, with an open canopy and a sparse cover of low shrubs; (5) *Abies lasiocarpa*/*Vaccinium scoparium* forests of the subalpine zone (2000–2250 m), which are characterized by a moderately dense tree stratum and a sparse cover of low shrubs; (6) *Pinus albicaulis*/*Vaccinium scoparium* forests of the timberline zone (2250–2550 m); (7) *Stipa occidentalis* grasslands of low to mid-elevation (1500–2000 m) slopes, subject to frequent avalanching; and (8) subalpine meadows (2100–2400 m) codominated by *Carex* sp. and forbs. Detailed floristic descriptions of these vegetation types can be found in Cole (1977); nomenclature follows Hitchcock & Cronquist (1973).

I was careful to insure that the amounts of use were approximately equal in all of these vegetation types. Samples were confined to the most heavily used trail in the wilderness area, the West Fork of the Wallowa River Trail, which serves primarily as a transportation route to the subalpine lakes. Few people fail to hike the complete trail, so levels of use are relatively constant along the trail. In addition, day-use and campground areas were avoided because these areas receive abnormally high levels of use.

Trailside and undisturbed vegetation were compared by establishing transects of quadrats perpendicular to the trail. Each transect consisted of three sample quadrats, located immediately adjacent to the trail, 2 m from the trail, and 10 m from the trail; each

quadrat measured 0.5 m × 1 m, with its long axis parallel to the trail. Within each quadrat, the percentage cover of each understory species was estimated (Daubenmire 1959).

Ten replicate transects were taken in each vegetation type. Data from these ten replicates were combined to derive the mean frequency and percentage cover of each understory species in each of the three quadrat locations in each of the eight vegetation types. These values were transformed into relative frequency and relative cover by dividing each individual frequency and cover value by the sum of the frequency and cover values for all species at a given location and vegetation type. Finally an importance value was assigned to each species by taking the mean of the relative frequency and relative cover values.

Frequency and cover were both included in the importance value in order to emphasize different but complementary aspects of species importance. Frequency provides a measure of how consistently a species is present within the vegetation type and cover provides a measure of the areal importance of the species. Many authors have noted that frequency values vary with quadrat size (Greig-Smith 1964), but quadrat size remained constant in this study so the use of frequency is justified.

The reduction in plant cover and change in species composition which occurs along trails can be measured by comparing the plant cover and species composition in quadrats located adjacent to the trail with these same measures in the undisturbed quadrat, located 10 m from the trail. The percentage cover reduction (*CR*) close to the trail can be measured by

$$CR = \frac{(C_2 - C_1) 100}{C_2}$$

where  $C_1$  is the percentage cover in quadrat 1 (the quadrat closer to the trail) and  $C_2$  is the percentage cover in quadrat 2 (the 10 m quadrat).

Change in species composition can be quantified by a coefficient of floristic dissimilarity (*FD*), a measure related to Whittaker's (1975) percentage similarity. It can be found by

$$FD = 0.5 \sum |p_1 - p_2|$$

where  $p_1$  is the importance value for a given species in quadrat 1 and  $p_2$  is the importance value for the same species in quadrat 2. Again larger values indicate greater vegetation alteration along trails.

## RESULTS AND DISCUSSION

There were wide differences in the susceptibility of vegetation types to trampling, shown in both cover reduction and floristic dissimilarity (Table 1). Three vegetation types suffered a loss of cover greater than 57% and a change in species composition greater than 64%; three other vegetation types lost less than 37% of their cover and experienced a change in species composition of less than 44%.

Additional information is required for the interpretation of the floristic dissimilarity values, because a certain amount of dissimilarity results from inherent variability within the undisturbed vegetation. In order to determine the significance of this variability, it was necessary to measure the dissimilarity between the 10 m quadrat samples and other control samples located in the same vegetation types. Using frequency and cover data

from control samples reported in Cole (1977), I calculated floristic dissimilarity values for these eight vegetation types; inherent variability produced dissimilarity values ranging from 19–31%. This suggests that floristic dissimilarity between trailside and undisturbed vegetation should probably exceed 50% before it can be considered highly significant.

The vegetation types which suffered the most drastic changes in character were *Pseudotsuga menziesii*/*Physocarpus malvaceus* forest, *Picea engelmannii*/*Thalictrum occidentale* forest and *Abies lasiocarpa*/*Vaccinium scoparium* forest. These densely forested types have understoreys which are highly dominated by either mesophytic forbs or woody shrubs with brittle stems and branches. The dominants which decreased in importance along trails were: *Holodiscus discolor*, *Physocarpus malvaceus*, *Thalictrum occidentale*, *Vaccinium scoparium*, *Phyllodoce empetrififormis* and *Ledum glandulosum*. The major species which increased along trails were: *Fragaria vesca*, *Trifolium repens*, *Taraxacum officinale*, *Carex rossii*, *Juncus parryi* and *Sibbaldia procumbens*. These are all small plants with either ground-level leaves or protected perennating tissues, features which facilitate survival under trampling stress (Bates 1935; Dale & Weaver 1974; Liddle & Greig-Smith 1975).

TABLE 1. Cover reduction and floristic dissimilarity values for different vegetation types, derived by comparison of quadrats at varying distances from the trail

Vegetation type	Cover reduction (%) <sup>*</sup>		Floristic dissimilarity (%) <sup>†</sup>	
	A <sup>‡</sup>	B	A	B
<i>Pseudotsuga menziesii</i> / <i>Physocarpus malvaceus</i> forest	73	30	82	26
<i>Pseudotsuga menziesii</i> / <i>Calamagrostis rubescens</i> forest	37	0	36	28
<i>Picea engelmannii</i> / <i>Thalictrum occidentale</i> forest	64	50	64	16
<i>Pinus contorta</i> / <i>Vaccinium scoparium</i> forest	53	18	41	14
<i>Abies lasiocarpa</i> / <i>Vaccinium scoparium</i> forest	57	9	67	23
<i>Pinus albicaulis</i> / <i>Vaccinium scoparium</i> forest	22	–19	62	40
<i>Stipa occidentalis</i> meadow	38	4	44	11
Subalpine meadow	12	0	37	30

<sup>\*</sup> Cover reduction is the percent decrease in vegetation cover observed in quadrats adjacent to the trail compared with those further away.

<sup>†</sup> Floristic dissimilarity is a comparison of the floristic difference between two quadrats (see text).

<sup>‡</sup> Column A compares trailside quadrats with those 10 m from the trail; column B compares quadrats 2 m and 10 m from the trail.

The vegetation types which appear to be least susceptible to change are the *Pseudotsuga menziesii*/*Calamagrostis rubescens* savanna, the *Stipa occidentalis* grassland and the subalpine meadow. These are open vegetation types with understoreys dominated primarily by graminoids, many of which are rhizomatous. The dominant species, *Calamagrostis rubescens*, *Stipa occidentalis* and *Carex* sp., decrease slightly close to the trail, but they still maintain vigour. Consequently, the change in species composition is less extreme and trailside sites maintain a relatively dense cover.

The *Pinus contorta*/*Vaccinium scoparium* and *Pinus albicaulis*/*Vaccinium scoparium* forests were moderately affected. *Vaccinium* decreased in both, but this affects the indices of change in opposing ways. The *Pinus contorta* forests lose a considerable amount of cover along trails, but species composition changes little. *Vaccinium* cover is reduced, but nothing invades the open sites, so there is little change in species composition. In the *Pinus albicaulis* forests, *Vaccinium* cover is reduced but there is a vigorous invasion of species from adjacent alpine openings. Consequently, there is a drastic shift in species composition but little loss of cover.

In mountainous wilderness areas it is currently a common practice to route trails away from meadowed areas and into the forests. These results suggest that this may be concentrating use in those vegetation types most susceptible to damage from use. Trails are visually more obvious in open areas and this visual impact may have been equated with ecological impact. In more densely forested areas, trailside changes are less obvious but more drastic. This emphasizes the need for widespread utilization of techniques which can predict the susceptibility of vegetation to trailside change. The simple method described in this paper can provide this type of information. From this data base, a manager can more effectively design trail systems which minimize alteration of the natural vegetation.

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